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THE INFLUENCE OF MENTAL AND MUSCULAR WORK ON NUTRITIVE PROCESSES.

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We often wonder at the marvels of modern surgery and the wonderful advances made in surgery during the past fifty years. At the same time we are often surprised by the fact that medicine as such has not made corresponding advances and that doctors are inclined now to give less medicine than ever before. In one particular, however, medicine has made wonderful strides, namely, in the so-called "preventive" medicine. In fact, it is a common newspaper joke that ere long we will be employing our doctors and paying them only during such a period of time as they keep us well and thus stimulate their efforts towards using preventive medicine to its fullest. Pasteur, Lord Lister and Koch are household names today and stand for wonderful series of painstaking researches which have developed the fact that many diseases formerly thought inevitable in the course of a lifetime can, by reasonable care, in a large number of cases be avoided.

In order to bring preventive medicine to the present successful stage, innumerable experiments, involving microscopy, chemistry and physiology, were necessary to demonstrate in just what manner these baneful organisms (for in many instances they have proved to be organisms) enter into our bodies and produce diseases. Modern hygiene is based in large part upon the bacteriological researches of these pioneers.

It is my privilege to explain to you how it is hoped to develop another line which, while it has by no means the attractive outlook presented by bacteriology and preventive medicine in general, may yet prove to be of the greatest value to mankind. I refer to investigations in the nutrition of man. If by proper study we can find what foods are best adapted to different purposes, if in what quantities they should best be ingested, what preliminary treatment is most desirable, we will have solved a great many problems regarding the diseases of digestion and will have made a large contribution to a wider branch of preventive medicine.

While the compound microscope can be used for studying the tissues, it requires a very different type of apparatus for studying the changes that take place in the whole body and the apparatus which, in our investigations, compares in a way to the compound microscope of the bacteriologist has the formidable name of respiration calorimeter. The microscope can reveal to us clearly what happens after the tissue is dead; it cannot, except in a few instances, give us a true picture of the processes which take place in the living body. These processes are extremely complex but we do know that as a result of food ingested, we obtain from the body heat, muscular work and mental work, and that there are certain excretions. During youth there is also a noticeable growth, while after the growth has been established, there is also repair of waste tissue. It is in studying these particular functions that we find it necessary to resort to a special apparatus—the respiration calorimeter.

We eat a great variety of foodstuffs and it is necessary for the body to so break down and rearrange the materials in these foods that the body can make the best use of them. For example, ordinary sugar cannot be used directly by the body but must first be broken down into dextrose and this dextrose is probably in part converted into another compound which is distributed through the muscles and particularly in the liver—a substance very closely allied chemically to sugar and called glycogen.

Like the frontiersman building his log house, the standing tree is of no use to him, but after the tree has been felled and the log hewn into the proper shape, then and then only can he begin to construct his house. But it is only during youth that the body is particularly engaged in building new tissue and the chief object of these rearrangements of the materials of the food is to so deposit the material in the various parts of the body that it can be used as fuel and be properly burned or oxidized. While, then, the food is first acted upon by the various digestive juices to prepare it for use by the body and as a result of digestive processes, the original material of the food is transformed to substances more or less closely resembling the components of the body, it is true, however, that when the body has completely and finally utilized these products, in general they are broken down to relatively simple compounds.

When coal or wood are fed to the boiler in the power house, heat is liberated and from the heat can be obtained power. In burning, the coal or wood is converted in large part into two simple products, carbon dioxide and water vapor. In order to convert the fuel into carbon dioxide and water, a large amount of oxygen gas is consumed and this, as you know, is obtained from the atmosphere.

We have frequently been told that the body is a good deal like a machine and consequently we can subject the body to tests very much like those given to a machine. For example, we can consider the food like coal—a fuel to the boiler in the boiler room—and the respiratory gases like the fuel gases leaving the chimney, and the feces and the urine like the ashes. With the boiler it is relatively simple to get a sample of the coal and analyze it and to take a sample of the ash and see what unburned portion of the material is present. It is somewhat more complex to take a sample of the flue gases and see how much unburned material passes up the chimney, but it is infinitely more difficult to make an experiment on a man. While we can analyze food, urine and feces, when we come to the respiratory gases, we must have a special respiration apparatus for the purpose.

Briefly, it is an air-tight copper-walled box, through which a ventilating current of air is passed. The air leaving the chamber contains carbon dioxide and water vapor produced by the man and is deficient in oxygen which has been taken out of it by the subject; this air is passed through purifiers where the carbon dioxide and water are removed and then the air is returned to the chamber to be breathed over again, but before entering the chamber, the deficiency in oxygen is made up by admitting pure oxygen out of a steel cylinder, such as is used by a physician at the bedside.

It is possible with an apparatus of this type, then, to determine how much carbon dioxide and water are produced in twenty-four hours and how much oxygen gas is absorbed. If, together with

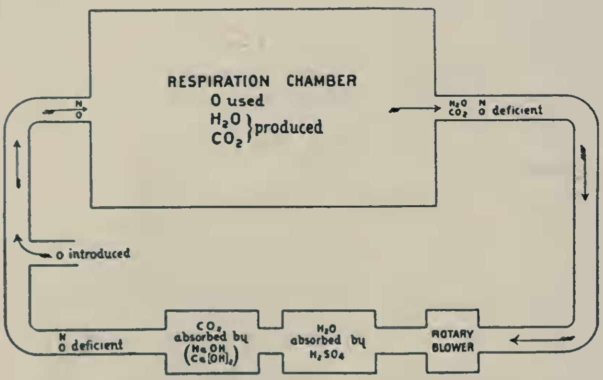

FIG. I. Schematic outline of ventilation system in the respiration calorimeter at Wesleyan University, Middletown, Conn.

these data, we have the analyses of the urine and the feces, it gives us a very perfect picture of the transformations that have taken place inside the body during the period the subject has been inside the respiration chamber.

With the boiler, this is about as far as we can ordinarily go, as there is no satisfactory method for measuring the total amount of heat given off by the boiler in a large power house, but with a man it is possible to measure not only the products of combustion and the oxygen consumed but also to measure directly the amount of heat produced by the oxidation or combustion of the substances inside the body. This is the calorimetric feature of the apparatus. The air-tight copper box is surrounded by a number of cases which gives it a refrigerator type of construction and provision is made for the prevention of any loss of heat through the walls. There being no loss of heat, the man, acting as a small furnace, would soon produce enough heat to make him very uncomfortable. An ordinary man at rest gives off about as much heat as a 32 c.p.

electric lamp, 100 calories, so it is necessary for us to bring away the heat from the chamber as fast as it is liberated, or otherwise the man would become uncomfortably warm. As in the winter our houses are heated with hot water, this little house is cooled by cold water. Through a series of pipes inside the chamber is passed a current of cold water, then by noting the temperature at which the

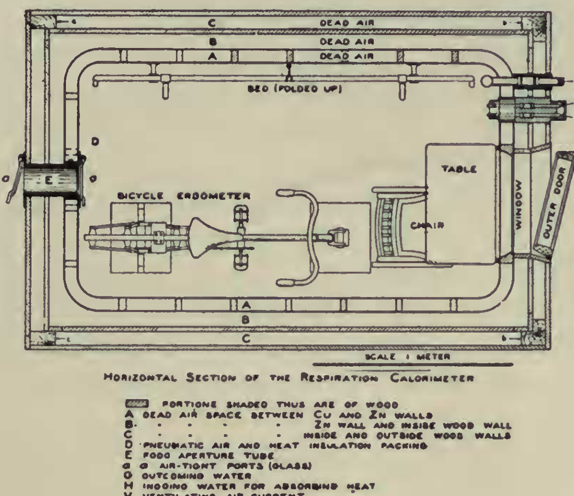

FIG. 2. Horizontal section of the respiration calorimeter showing heat insulation.

water enters and at which it leaves the chamber and the amount of water passing through, it is very easy to determine the exact amount of heat brought away in this manner. Thus this apparatus is well named a respiration calorimeter, "respiration" because it is an apparatus for measuring the respiratory processes and "calorimeter" because it measures the heat given off by the subject.

It is difficult for us to imagine that there may be heat or energy in a glass of ice cream soda or a piece of toast or a slice of ham and yet there have been one or two rather remarkable instances where some of our foodstuffs have been by force of dire necessity put to practical use for the production of heat. A few years ago the farmers of Kansas had an over-supply of corn and with the price of fuel as it was at that time, it became a common practice among the Kansas farmers to actually burn corn. Several years ago, a large wheat steamer became stalled in lake Huron and in working her way against the ice for several days, exhausted her fuel supply. As a matter of fact, she was brought into Detroit by burning the wheat in her bins under the boilers. One of the most striking instances that I ever heard of was one that occurred on a coastwise steamer bound from Boston to one of the Maine ports. This steamer in the latter part of the year found herself encountering a severe gale and shortly the coal supply was wholly exhausted. Recourse was had to the demolition of the interior woodwork of the vessel, stateroom partitions, mattresses, furniture, but as a matter of fact, the steamer was brought into Portland harbor by burning a large cargo of hams under her boilers.

As we commonly eat our food materials, for the most part they are too moist to burn, although when the different food materials are deprived of a greater part of their moisture by drying, they burn quite readily. In so burning, they are converted to carbon dioxide and water and a definite amount of heat is liberated during this combustion.

Whenever organic material is burned and completely oxidized to carbon dioxide and water, there is a definite amount of heat liberated for each gram burned. Fats liberate very much more heat than do equal weights of sugars or starches, and protein, the third important element in our food, liberates about the same amount of heat as do the carbohydrates. If, therefore, we determine as we can with a special apparatus, the heating value or fuel value of different ingredients in our diet and then measure the total amount of food ingested, measure the heat produced by man and make due allowance for the heat in the feces and the solid matter of the urine, it is possible for us to strike a complete balance of income and outgo of energy and see whether our measurements are in error or not. So, on the one hand, we have a heat balance obtained by determining the intake and fuel and the output of unburned material in the ash and the heat directly produced. On the other hand, we have from the chemical analyses of the respired air and the excreta a means of knowing just how much protein, how much fat, and how much carbohydrates have been burned in the body during a certain experiment. If our chemical analyses have been accurate, we should be able to compute from the fuel values of protein, fat and carbohydrate thus obtained the heat these substances would be expected to produce when burned in the body. Obviously, this result should compare with the results as actually determined. When our apparatus functionates so perfectly that we can secure results in this way, we can feel that we are on safe ground and our results give us a very perfect picture of what takes place in the body. Having found such an apparatus and method, it only remains for us to apply this apparatus in as many ways as time and expense will permit.

Among the numerous questions that can be solved by an apparatus of this type is the effect of work on changes in material in the body, which we call metabolism. We know that when a man is sitting quietly at rest in a chair, he gives off, say, 100 calories of heat per hour. This is about the amount of heat given off from a 32 c.p. electric lamp. If, however, a man stands up and walks about, we have found that his heat production rises considerably and we find, also, that not only does the heat elimination increase but the carbon dioxide in the breath increases correspondingly.

Muscular exercise with varying degrees of intensity produces varying amounts of carbon dioxide and heat as is shown by the table

TABLE I.

Average Normal Output of Carbon Dioxid and Heat from the Body.

Conditions of Muscular Activity.	Average Quantities per Hour. Carbon Dioxid. Gms.	Heat. Cals
Man at rest, sleeping	25	65
Man at rest, awake, sitting up	35	100
Man at light muscular exercise	55	170
Man at moderately active muscular exercise	100	290
Man at severe muscular exercise	150	450
Man at very severe muscular exercise	210	600

herewith. The classification of muscular exercise on this basis is very unsatisfactory, as different people may have different impressions of what is meant by "moderately active muscular exercise," for example. It is certain, however, that under these conditions, the characterization so far as the sleeping period is concerned is pretty well fixed and it is also true that man at very severe muscular exercise means practically the limit of human endurance.

Using the values in this table it is possible to roughly compute the average daily output of heat from a man at light muscular work or the heat from a man with different degrees of muscular work. Assuming, for example, that the man is at light muscular work, the computation is as follows as given in Table II herewith.

TABLE II.

Average Daily Output of Heat of a Man at Light Muscular Work.

Daily Program.	Heat Output.
At rest, sleeping, 8 hours, 65 calories per hour	520
At rest, awake, sitting up, 6 hours, 100 cal. per hour	600
Light muscular exercise, 10 hours, 170 cal. per hour	1,700
Total output of heat, 24 hours	2,820

The computation of the average daily output of heat on this basis is at best somewhat unsatisfactory, as we do not know with sufficient accuracy the heat output during the various degrees of muscular activity. Nevertheless, it serves to give a general idea of the possibilities of using standard normal values for getting a rough approximation of the energy output of different men with different conditions of muscular activity.

We are all of us firmly of the opinion that when we are doing strenuous mental work, we are doing a great deal of work. We feel sometimes perfectly exhausted at the end of a severe mental task, and consequently it will be interesting to note to what degree mental work influences the interchange of material in the body. Does severe mental application call for a greater production of heat or a greater oxidation of the tissues? In order to test this question satisfactorily, it became necessary for us first to try to find out how to get men to work hard mentally for a period of several hours.

While at Wesleyan University, it occurred to me that it might be desirable for us to study the metabolism of students during the mid-year examination period, for if there is any time in which a college student performs mental work, it is during the examination period. Consequently it was arranged for students to take their examinations in the respiration calorimeter.[1] The chamber is large, fairly well lighted, quiet, with a good ventilation and every possible convenience for quiet, sustained mental effort without distractions. The men entered into the experiments heartily and twenty-two such experiments were made. In order to control the experiments and give us a basis for comparison, the same men were on subsequent days placed in the calorimeter for the same length of time, during which period no mental work was done and, indeed, we went so far as to attempt to eliminate the results of the muscular work of writing by giving them plain copying to do on paper in the control period. By this means we were able to compare the results of the experiments with mental work with the control experiment. During these mental work experiments, the men were encouraged to note down all their personal impressions. Some of the observations were very interesting. Several men said it began to grow cold and then to grow warm, while as a matter of fact, the temperature of the chamber did not vary by more than two or three hundredths of a degree. Other men noted that they perspired freely during the examination period and that they had been under a tremendous strain and effort.

TABLE III.

METABOLISM DURING MENTAL WORK.

(Quantities per hour.)

	Examination Period.	Control Period.
Carbon dioxide	33.4 grams	32.8 grams
Oxygen	27.3 grams	25.9 grams
Water vapor	39.2 grams	37.8 grams
Heat	98.8 calories	98.4 calories

Averages of 44 experiments.

But all of these personal impressions fall wholly out of consideration when we compare the results of the experiments with the students during the examination period and during the control period. There was practically no difference between the results with

[1] For a detailed discussion of these experiments see Benedict and Carpenter, "Muscular and Mental Work and Efficiency of the Body as a Machine," United States Department of Agriculture, Office of Experiment Stations, Bul. 208, 1909.

the men during the mental tests and during the control periods. This, to the layman, is certainly a most surprising outcome, for, as you know, it is the popular impression that a sustained mental effort results in a complete physical exhaustion. Here, then, is a problem that is pretty thoroughly solved by means of this large apparatus which had been constructed for experiments of exactly this kind.

I ought to add here, perhaps, that incidentally among the old legends that have been handed down to us and still find credence in public opinion is the belief that fish is an excellent brain food. This has long been wholly exploded. In fact, it has been easily traced to an old saying of Professor Moleschott,— "Ohne Phosphor kein Gedanke," and as fish is known to contain phosphorus, it was thought that fish was an excellent brain food for mental workers. As a matter of fact, there are no researches that show that there is any influencing of the chemical processes of the body as a result of mental exertion.

Of special interest, perhaps, from the standpoint of hygiene in these experiments is the fact that several of the men expressed a feeling of restraint and a lack of freedom to stretch themselves and possibly to move about somewhat as a result of staying in the chamber. Of course our experiments would have been seriously inconvenienced if the men had moved about freely, so that we asked them to diminish as much as possible all extraneous muscular exertion other than that required in using the pen. This longing for the use of the arms and body during mental exercise is simply another means of indicating that our bodies need as perfect circulation in all parts as possible, that when long-continued and cramped positions are maintained, there is a feeling of uneasiness and discomfort.

It is a most wise and growing custom for book users to vary the body position during sustained mental work. The increasing use of the standing desk while reading, and the pacing of the floor during mental work or dictation of addresses and literary productions testify to the fact that for best mental effort, there should be physical exercise, though this is far from affirming that the center rushes invariably become literary men. In our studying we should certainly pay more attention to physical exercise and fresh air, and the old picture of the bookworm with his feet on the top of the desk, the back hunched into an arm chair and the head enveloped in tobacco smoke can hardly be considered as portraying the ideal condition for creative work in the light of modern physiology and psychology.

Muscular Work.

While mental effort is without appreciable influence on metabolism, I now wish to call to your attention a most interesting series of experiments on the influence of severe muscular work, particularly such as bicycle riding, upon the transformations of the body. The narrow confines of our respiration chamber make it necessary for us to restrict our experiments to those forms of muscular activity that do not require a large amount of apparatus or large space. A form of stationary bicycle called a bicycle ergometer is ideal for such experiments. We placed inside the respiration chamber a stationary bicycle, the rear wheel of which was replaced by a large copper disk rotating in a magnetic field. With this apparatus it was possible to put an electric brake, so to speak, on the copper disk and make it more or less difficult to drive the pedals Without going into details, I will simply say that it is possible to calibrate this apparatus and to know that every revolution of the pedals with varying strengths of the electric brake results in the transformation of a definite amount of energy into heat, consequently when a man rides, we have only to count the number of revolutions of the pedals to know how much heat has been transferred from the muscles of his body to the pedals in the form of effective work. This apparatus, together with the respiration chamber, has given us a means of studying man as a machine in a way that I think has never been done before.

One of the important problems of interest to the engineer is the efficiency of his engine. How much energy of the coal can a power plant convert into effective mechanical work? Obviously, the best power plant is that which produces the best mechanical work out of one ton of coal. With man, we also have a machine. The fuel in the boiler is again the food and the muscles are the levers by which the energy is transferred from the muscles to some effective apparatus so that it can be used as external work. This apparatus, the bicycle ergometer, is admirably adapted for the use of the powerful leg muscles and hence we were able to study this to a considerable degree.

The experiments were made something in this way. The subject was first placed in the respiration chamber for part of a day and the heat production measured during rest, while he was sitting quietly reading a book. This is our "base line," as the surveyor says, or our basis for comparison. On subsequent days similar

Fig. 3. Bicycle ergometer for studying problems relating to muscular work.

experiments are made in which the man rides the bicycle ergometer with varying resistance of the electric brake. During these experiments the heat production and the carbon dioxide eliminated are measured directly and also the amount of work in terms of calories put on to the bicycle accurately determined by noticing the number of revolutions of the pedals. We thus have a determination of the total heat production and the heat of mechanical work which we can compare with the total heat production and thus find the efficiency. The degree of resistance of the electric brake varied from mere coasting when no resistance is applied but the legs were made to rotate as in coasting down a hill without a coaster brake, to such a high resistance that the wheel would hardly be carried by the dead point. The subjects used for these experiments varied. Two of them, coming out of the wild woods of Maine, had never seen a bicycle. Others were college athletes and were on the college track team, and finally one of the most interesting experiments was made with one of America's professional bicyclists, Mr. Nat Butler of Cambridge.

In Table IV, I have summarized a number of experiments with these different subjects.

TABLE IV.

EXPERIMENTS ON BICYCLE RIDERS.

(Calories per Hour.)

	Resting.	Working.[2]	Work Done.	Efficiency, Per Cent.
J. C. W.	112	339	49	21.6
B. F. D.	106	318	45	21.2
A. L. L.	105	326	46	20.8
E. F. S.	117	399	51	18.1
N. B.	92	619	112	21.3
		471	79	20.8
		401	65	21.0
		382	60	20.7

In the first column under the title "resting" is recorded the number of calories produced per hour by these different men when sitting quietly reading in the respiration calorimeter. These experiments are almost identical in their nature with the control experiments in the mental work experiments and are intended to show the heat requirement for maintenance during rest. These men gave off, as you see, not far from 100 calories per hour, which again is about the heat production of a 32 c.p. lamp. As they were

[2] Including heat produced by the ergometer.

all of athletic build, the heat production is somewhat larger than would be expected from men in sedentary occupations and you will remember in the mental tests, the heat production per hour averaged 99 calories. The average here is a little higher and is readily accounted for by the fact that the men were muscular. In the second column is recorded the heat production per hour during the period when the subjects were engaged in severe muscular work on the bicycle ergometer. Here the differences between the different subjects are very great. The lowest heat production was in the case of B.F.D. 318 calories, and the highest nearly twice as great, namely, 619 calories by N.B. While at first sight, it would appear that there was a very marked difference in the work or efficiency from these figures given in this column, it is necessary for us first to find out how much of this enormous heat production was actually converted into mechanical work, and we find that in the third column there were very large differences in the amounts of work accomplished by these men. These differences can be explained on two grounds, first, the rate of revolution of the pedals was different, and second, the degree of resistance in the electric brake was very different. It is interesting to note that the first three men during work gave off about 330 calories per hour and accomplished about 46 to 47 calories of effective work, thereby showing very little difference in either the total heat production or in the work done. The fourth man, E.F.S., gave off considerably more heat during the working period and also accomplished more work; and then we come to the astounding results of the experiment with Mr. Butler in which he gave off 619 calories and accomplished the enormous amount of 112 calories of muscular work. The remaining experiments with Mr. Butler were made with the idea of decreasing the muscular work and noting the effect on the heat production. You can see in a general way that when the total heat falls off, the work done falls off.

Perhaps of greatest interest is the comparison of these different men with regard to their efficiency. There are a number of methods whereby the efficiency can be computed from the figures given in the table. Theoretically we can say that in the first instance for every 49 calories of heat produced, there were required 339 calories of total energy. This would give us an efficiency of not far from 14 per cent. On the other hand, another method of computing the efficiency, and perhaps one that is fairer, is the method in which the total resting metabolism is deducted from the total heat production and we compare the work done with the increased amount of heat required to do this work. Thus, in the first experiment out of 339 calories produced during work, 112 calories can reasonably be assigned to the production necessary for maintenance while the subject is sitting quietly reading in the calorimeter. Deducting the 112 from 339, we find that 227 calories of heat result in the production of 49 calories of efficient work. On this basis, the efficiency is 21.6 per cent. A similar calculation for the other subjects shows the remarkable fact that there are but slight differences between these men as regards their efficiency. In other words, for every calorie of efficient muscular work done, there are about 5 calories of extra heat produced. In the case of the enormous heat production of Mr. Butler, we find that the differences in the two methods of computation are not as noticeable for it makes but a small change in the percentage whether we divide 112 multiplied by 100 by 619 or whether we divide 112 times 100 by 527. In the latter case, the efficiency is 21.3 per cent., while in the first it is about 18 per cent. Obviously, the greater the amount of work accomplished per hour, the less the influence of deducting the resting metabolism.

How does a man compare with an engine as regards efficiency? I have no doubt but that some fault could be found with my reasoning when attempting to compare a man with a machine but the best steam engines of the present day do not average an efficiency much greater than 14 per cent. Certain internal combustion motors realize somewhat more. At any rate, we can say that a man is a wonderfully efficient machine.

The figures in Table IV shed a most interesting light on the question of training. It has commonly been supposed that when a person is trained, the muscles become more effective and consequently there is a greater production of work for the same expenditure. In these figures here we find that in the first place the two men, A.L.L. and E.F.S., who were wholly untrained, and indeed wholly unfamiliar with the bicycle, accomplished as much work as did the college athletes, J.C.W. and B.F.D., and, indeed, with an efficiency very little less than that of the first two. When we come to the figures of Mr. Butler, we find that he was able by virtue of his skill and strength to accomplish a very great deal *more* work than any of the other men, but as a matter of fact, his *efficiency* was not materially greater than that of the college athletes, or indeed, the untrained men. So far as these two untrained men are concerned, their training consisted in riding the bicycle ergometer one half hour the first day and a half-hour increase for each succeeding day for six days prior to the test. Thus on the sixth day they rode three hours at one stretch and the total training occupied but 10.5 hours. This was done in an attempt to accustom the leg muscles to the exercise before the experiment began, so that they would not be sore when used in the subsequent experiment, so while they did have a small amount of training, it was far from the ordinary training a college athlete would pass through in preparing for an intercollegiate contest. It is obvious that Mr. Butler was able to accomplish an enormous amount of work by virtue of his long experience and well-developed musculature, but it is indeed astounding that his muscles had no greater efficiency than did those of much less trained college athletes.

It is very clear from these experiments that in order to produce muscular work, there must be a very large by-production of energy in the body. When we consider that a man at rest, sitting quietly, requires 92 calories for his maintenance, and when we know, as we do from other experiments, that the same man asleep would require not far from 60 calories, we see that in Mr. Butler's case during a severe muscular work period, there was a heat production in his body amounting actually to 10 times that when he was asleep.

In order to produce this heat in the body there must have been combustion, vigorous combustion, combustion either of body substance, in case the subject did not have food enough, or combustion of food material previously eaten. We have found as a result of a large number of experiments that a man at rest, doing no visible external muscular work, requires not far from 2,000 calories for maintenance during twenty-four hours. You can see that in three hours Mr. Butler produced nearly this amount when at severe muscular work; consequently he must have burned up in these three hours as much material as would ordinarily be burned by a subject at rest in twenty-four hours. On this same basis, he would need three meals every three hours or one square meal an hour.

I think figures like these go to show most conclusively that the proposition we hear frequently made to cut down our total food consumption is founded on entirely erroneous grounds. If we do muscular work, we must burn up material. We must draw on body substance or we must supply food. I have no doubt that many of us are too fat, not grossly over-weight, but somewhat over. People of sedentary habits have a tendency to take on weight and become 25 or 30 pounds over-weight without much difficulty, but I contend that the average man is not too fat and that his diet is not too large for him. People say continually, "We eat too much." Doubtless at times we do eat too much. I have no doubt that every one of us remembers the feeling of satiety with which we rose from our last Christmas dinner. Doubtless this feeling of satiety was carried farther than health, and in some cases, good breeding would justify, but Christmas dinners are not an everyday occurrence and it is not logical to say that because we over-eat on one day, that we continually over-eat.

It is the custom of athletes in general to consume large amounts of proteid food, particularly beef, eggs and milk. There is a tradition which has been handed down for many years that this diet is best suited for athletes, and that a large quantity of protein is advisable for a high efficiency and large and sudden drafts on strength. It is beginning to be questioned whether or no this after all is the logical diet for training. I have not time to go into this discussion, but there are at present some very strong advocates of a low protein diet, both for ordinary life and for athletic training and while in my mind their case is far from proven, some of the arguments are certainly most striking in their effectiveness, showing that our good friends, the vegetarians, have developed a remarkable degree of endurance when compared with their meat-eating competitors. All of these problems will gradually be worked out and on a sound scientific basis, but they have nothing to do with the general fact that when muscular work is accomplished, food must be supplied, and we cannot cut down our diet without losing flesh and simultaneously cutting down our muscular work. A great many men who consider themselves as living a sedentary life, actually, accomplish much more muscular work than they realize. For example, I have made an experiment a good many times by carrying a pedometer. During one winter when I was writing a large report and my exercise was confined to walking to and from the laboratory, two blocks from my house, and going about among the workers in the laboratory, I thought I was doing a very small amount of work, having almost no exercise, and yet I found to my astonishment that I recorded almost unerringly every day a distance walked of about seven miles. Obviously during that winter, since I held my body weight, my food must have been instinctively so adjusted as to exactly supply the demands required for the winter's work. When we consider that the intake of food is determined in a large measure by appetite and the feeling of satiety and the consumption of the food is dependent on the muscular activity, I do not know any factor regarding the body functions that is any more delicately adjusted than is the balance between the intake of food and the food requirement.

I think, then, we can take it as thoroughly settled that for the large majority, if the appetite is ordinarily followed, it will result in a most perfect adjustment of the food intake to the food requirement. Obviously it is important that we select foods that agree with us; excessive amounts of sweets and foods difficult of digestion are certainly to be avoided, but whether we follow the no-breakfast or the no-dinner or the no-supper plan, it is absolutely certain that in the course of twenty-four hours, or perhaps in the course of one week, what we lost in the meal voluntarily given up is compensated by increased consumption at the other meals. This I know is contrary to personal impression but we must, if we wish to make accurate observations on our diet, wholly eliminate our personal impressions. Nothing but the scales and an accurate table of analyses of food materials will give us results of any value. My personal belief is that instead of giving up one or two meals a day, it would be better for us to eat more often and less in amount. Particularly is this the case with those who are desiring to reduce the body weight. It is sometimes amusing to think of people who are going through all kinds of muscular exercise to work off their fat and at the same time these muscular exercises are stimulating a most voracious appetite which must be appeased. In my judgment, instead of decreasing the consumption of food to reduce the fat of the body, it is better to produce a feeling of satiety and thus cut down the ravenous appetite. This can, I believe, best be done by more frequent small meals than by leaving out any one meal and eating to complete satiety at the others.

I have outlined to you very hastily this evening a few of the important problems that we are able to study by means of the respiration calorimeter. These researches that I have thus far outlined were carried out in the chemical laboratory of Wesleyan University and it may be of interest to you to know that the researches were deemed so important that a special laboratory has been constructed for their prosecution in Boston—the Nutrition Laboratory of the Carnegie Institution of Washington—where it is hoped to study more accurately the questions relating to health and, indeed, to disease. The laboratory is located near the Harvard Medical School and in the vicinity of a large number of hospitals which are either built or are planned. In this way we hope to be able to get into most intimate touch with pathological material.

At Wesleyan University only one calorimeter was used for all the different kinds of experiments, but in the new laboratory three calorimeters are already completed and two others projected, thus providing an apparatus which will be particularly adapted to the kind of experiment planned. In the chair calorimeter a large number of experiments have already been made with diabetic subjects, and the bed calorimeter has been used for studying bed-ridden patients, not only for those having diabetes but a most interesting series of observations have also been made on women before and after confinement. The laboratory is also thoroughly equipped for studying all the excreta and many problems involving muscular work.